ISRCTN84840541 https://doi.org/10.1186/ISRCTN84840541

Understanding how nighttime railway noise and vibration affect sleep and blood markers of metabolic health

Submission date
26/01/2026

Recruitment status
No longer recruiting

Registration date
28/01/2026

Overall study status
Completed

Last Edited
28/01/2026

Condition category
Nervous System Diseases

[X] Prospectively registered
[X] Protocol
[X] Statistical analysis plan
[_] Results
[_] Individual participant data
[X] Record updated in last year

Plain English summary of protocol

Background and study aims
This study explores how rail freight noise and vibration affect sleep, heart function, metabolism, and thinking skills. The goal is to understand how typical urban noise and vibration may influence overall health and daily functioning.

Who can participate?
Healthy adults aged 18–30 years living in the Gothenburg area with normal hearing, regular sleep patterns, no diagnosed sleep disorders, and not using sleep medication.

What does the study involve?
Participants will spend five nights in a sleep laboratory. The first night is for acclimatization. The following nights include one quiet night and three nights with simulated rail noise and vibration. Sleep, heart function, and activity will be monitored using non-invasive sensors. Each morning, participants will give a small blood sample and complete cognitive tests. Questionnaires and wrist monitoring will track sleep, alertness, and daily activity.

What are the possible benefits and risks of participating?
There is no direct benefit. Risks are minimal and may include mild sleep disturbance, temporary discomfort from wearing sensors, or minor discomfort and bruising from blood sampling.

Where is the study run from?
University of Gothenburg, Sweden.

When is the study starting and how long is it expected to run for?
February 2026 to June 2026, with each participant involved for five nights.

Who is funding the study?
The Swedish Transport Administration (Trafikverket)

Who is the main contact?
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Contact information

Type(s)
Principal investigator, Public, Scientific

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Additional identifiers

Swedish Transport Administration (Trafikverket) grant
TRV 2025/13983

Study information

Scientific Title
Combined effects of railway noise and vibration on sleep and health markers

Acronym
Convoy

Study objectives
To determine the biological and neurobehavioural consequences of sleep disruption caused by railway vibration and noise, including cardiometabolic and cognitive function.

Ethics approval required

Ethics approval required

Ethics approval(s)
Approved 09/12/2025, Ethics Review Authority (Etikprovningsmyndigheten) (Box 2110, Uppsala, 75002, Sweden; +44 010-475 08 00; registrar@etikprovning.se), ref: 2025-07915-01

Primary study design
Interventional

Allocation
Randomized controlled trial

Masking
Blinded (masking used)

Control
Dose comparison

Assignment
Crossover

Purpose
Basic science, Health services research

Study type(s)

Health condition(s) or problem(s) studied
Combined effects of railway noise and vibration on sleep, biomarkers of cardiometabolic function and cognitive performance in healthy adults.

Interventions
The study is a prospective, within-subject cross-over trial conducted in the Sleep and Environmental Laboratory. Participants complete five consecutive overnight laboratory sessions, including a habituation night, a control night, and three intervention nights. The habituation night familiarises participants with the laboratory environment and study procedures and is excluded from outcome analyses.

During the control night, participants sleep without exposure to railway noise or vibration, providing a baseline for sleep, cardiometabolic, cognitive, and affective outcomes. During the three intervention nights, participants are exposed to simulated railway freight noise and vibration at urban levels . Each night includes 36 train events randomly distributed across an 8-hour sleep opportunity. In these three intervention nights (Night A, Night B and Night C), the levels of the railway noise and vibration are presented in different combinations (e.g. high vibration and low noise) to allow assessment of their individual and combined effects. The maximum vibration is 0.9 mm/s (with Swedish comfort weighting) and the maximum noise is 55 dB LAF,max.

All conditions are administered overnight in assigned bedrooms (23:00–07:00). Physiological sleep is monitored continuously using ambulatory polysomnography (PSG), and cardiac activity is recorded using electrocardiography (ECG) and finger photoplethysmography (PPG). No pharmacological treatments are administered.

The order of control and intervention nights is randomised using a Latin square design, with participants acting as their own controls. Daytime sleep is prohibited and monitored using wrist actigraphy. Caffeine intake is restricted after 15:00, and alcohol is prohibited. Participants consume consistent evening meals, recorded in food diaries. Screen time is monitored using the "Screen Time and Sleep" app throughout the pre-laboratory and laboratory periods.

Additional assessments include morning blood samples for plasma metabolomics, insulin, and glucose, morning and evening computerized cognitive testing, and questionnaires assessing baseline health, sleep, noise sensitivity, daily sleepiness, mood, and noise-induced disturbance.

Intervention Type
Behavioural

Primary outcome(s)
1. Fasting insulin resistance measured using the Homeostatic Model of Insulin Resistance (HOMAIR), which incorporates insulin concentrations measured by a Chemiluminescent Microparticle Immunoassay (CMIA) and blood glucose levels quantified using an enzymatic hexokinase/G6PDH method at morning immediately after the exposure to control night

2. Fasting insulin resistance measured using the Homeostatic Model of Insulin Resistance (HOMAIR), which incorporates insulin concentrations measured by a Chemiluminescent Microparticle Immunoassay (CMIA) and blood glucose levels quantified using an enzymatic hexokinase/G6PDH method at morning immediately after the exposure to intervention night C

3. Fasting insulin resistance measured using the Homeostatic Model of Insulin Resistance (HOMAIR), which incorporates insulin concentrations measured by a Chemiluminescent Microparticle Immunoassay (CMIA) and blood glucose levels quantified using an enzymatic hexokinase/G6PDH method at morning immediately after the the exposure to intervention night B

4. Fasting insulin resistance measured using the Homeostatic Model of Insulin Resistance (HOMAIR), which incorporates insulin concentrations measured by a Chemiluminescent Microparticle Immunoassay (CMIA) and blood glucose levels quantified using an enzymatic hexokinase/G6PDH method at morning immediately after intervention night A

5. Total sleep time measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

6. Total sleep time measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

7. Total sleep time measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

8. Total sleep time measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

9. Total amount of N1 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

10. Total amount of N2 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

11. Total amount of N3 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

12. Total amount of rapid eye movement (REM) sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

13. Total amount of rapid eye movement (REM) sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

14. Total amount of rapid eye movement (REM) sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

15. Total amount of rapid eye movement (REM) sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

16. Total amount of N1 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

17. Total amount of N1 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

18. Total amount of N1 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

19. Total amount of N2 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

20. Total amount of N2 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

21. Total amount of N2 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

22. Total amount of N3 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

23. Total amount of N3 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

24. Total amount of N3 sleep measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

25. Wakefulness after sleep onset (WASO) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

26. Wakefulness after sleep onset (WASO) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

27. Wakefulness after sleep onset (WASO) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

28. Wakefulness after sleep onset (WASO) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

29. Number of awakenings measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

30. Number of awakenings measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

31. Number of awakenings measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

32. Number of awakenings measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

33. Sleep onset latency (SOL) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control Night

34. Sleep onset latency (SOL) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

35. Sleep onset latency (SOL) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

36. Sleep onset latency (SOL) measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

37. Sleep efficiency measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to control night

38. Sleep efficiency measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night C

39. Sleep efficiency measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night A

40. Sleep efficiency measured using polysomnography/EEG, scored according to American Academy of Sleep Medicine guidelines at exposure to intervention night B

41. Sleep depth assessed using the odds ratio product (ORP) measured using polysomnography /EEG measurements at exposure to control night

42. Sleep depth assessed using the odds ratio product (ORP) measured using polysomnography /EEG measurements at exposure to intervention night B

43. Sleep depth assessed using the odds ratio product (ORP) measured using polysomnography /EEG measurements at exposure to intervention night C

44. Sleep depth assessed using the odds ratio product (ORP) measured using polysomnography /EEG measurements at exposure to intervention night A

45. Maximal change of odds ratio product (ORP) measured using polysomnography/EEG measurements at exposure to railway vibration and noise events

46. Area under the curve of odds ratio product (ORP) measured using polysomnography/EEG measurements and the trapezoid rule at exposure to railway vibration and noise events.

47. N-acetylglucosamine/galactosamine (GlycA) concentration measured using NMR analysis of blood plasma at morning after exposure to control night

48. N-acetylglucosamine/galactosamine (GlycA) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night C

49. N-acetylglucosamine/galactosamine (GlycA) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night B

50. N-acetylglucosamine/galactosamine (GlycA) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night A

51. Sialic acid (GlycB) concentration measured using NMR analysis of blood plasma at morning after exposure to control night

52. Sialic acid (GlycB) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night A

53. Sialic acid (GlycB) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night B

54. Sialic acid (GlycB) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night C

55. Supramolecular phospholipid composite (SPC) concentration measured using NMR analysis of blood plasma at morning after exposure to control night

56. Supramolecular phospholipid composite (SPC) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night C

57. Supramolecular phospholipid composite (SPC) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night B

58. Supramolecular phospholipid composite (SPC) concentration measured using NMR analysis of blood plasma at morning after exposure to intervention night A

59. Ethanol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

60. Ethanol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

61. Ethanol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

62. Ethanol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

63. Trimethylamine-N-oxide concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

64. Trimethylamine-N-oxide concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

65. Trimethylamine-N-oxide concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

66. Trimethylamine-N-oxide concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

67. 2-Aminobutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

68. 2-Aminobutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

69. 2-Aminobutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

70. 2-Aminobutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

71. Alanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after after exposure to control night

72. Alanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

73. Alanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

74. Alanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

75. Asparagine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

76. Asparagine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

77. Asparagine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

78. Asparagine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

79. Creatine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

80. Creatine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

81. Creatine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

82. Creatine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

83. Glutamic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after after exposure to control night

84. Glutamic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

85. Glutamic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

86. Glutamic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

87. Creatinine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

88. Creatinine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

89. Creatinine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

90. Creatinine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

91. Glycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

92. Glycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

93. Glycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

94. Glycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

95. Histidine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

96. Histidine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

97. Histidine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

98. Histidine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

99. Isoleucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

100. Isoleucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

101. Isoleucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

102. Isoleucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

103. Leucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

104. Leucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

105. Leucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

106. Leucine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

107. Lysine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

108. Lysine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

109. Lysine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

110. Lysine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

111. Methionine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

112. Methionine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

113. Methionine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

114. Methionine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

115. N,N-Dimethylglycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

116. N,N-Dimethylglycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

117. N,N-Dimethylglycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

118. N,N-Dimethylglycine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

119. Ornithine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

120. Ornithine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

121. Ornithine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

122. Ornithine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

123. Phenylalanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

124. Phenylalanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

125. Phenylalanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

126. Phenylalanine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

127. Proline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

128. Proline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

129. Proline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

130. Proline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

131. Sarcosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

132. Sarcosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

133. Sarcosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

134. Sarcosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

135. Threonine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

136. Threonine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

137. Threonine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

138. Threonine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

139. Tyrosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

140. Tyrosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

141. Tyrosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

142. Tyrosine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

143. Valine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

144. Valine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

145. Valine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

146. Valine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

147. 2-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

148. 2-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

149. 2-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

150. 2-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

151. Acetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

152. Acetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

153. Acetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

154. Acetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

155. Citric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

156. Citric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

157. Citric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

158. Citric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

159. Formic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

160. Formic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

161. Formic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

162. Formic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

163. Lactic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

164. Lactic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

165. Lactic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

166. Lactic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

167. Succinic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

168. Succinic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

169. Succinic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

170. Succinic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

171. Choline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

172. Choline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

173. Choline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

174. Choline concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

175. 2-Oxoglutaric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

176. 2-Oxoglutaric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

177. 2-Oxoglutaric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

178. 2-Oxoglutaric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

179. 3-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control night

180. 3-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

181. 3-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

182. 3-Hydroxybutyric acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

183. Acetoacetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

184. Acetoacetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

185. Acetoacetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

186. Acetoacetic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

187. Acetone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

188. Acetone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

189. Acetone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

190. Acetone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

191. Pyruvic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

192. Pyruvic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

193. Pyruvic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

194. Pyruvic acid concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

195. D-Galactose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

196. D-Galactose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

197. D-Galactose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

198. D-Galactose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

199. Glucose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

200. Glucose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

201. Glucose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

202. Glucose concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

203. Glycerol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

204. Glycerol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

205. Glycerol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

206. Glycerol concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

207. Dimethylsulfone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to Control night

208. Dimethylsulfone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

209. Dimethylsulfone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

210. Dimethylsulfone concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

211. Morning subjective sleepiness measured using Karolinska Sleepiness Scale at morning after exposure to control

212. Morning subjective sleepiness measured using Karolinska Sleepiness Scale at morning after exposure to intervention night C

213. Morning subjective sleepiness measured using Karolinska Sleepiness Scale at morning after exposure to intervention night B

214. Morning subjective sleepiness measured using the Karolinska Sleepiness Scale at morning after exposure to intervention night A

215. Self-reported sleep disturbance measured using on a 0-10 numerical scale, from "Not at all" to "Extremely" at morning after exposure to control

216. Self-reported sleep disturbance measured using on a 0-10 numerical scale, from "Not at all" to "Extremely" at morning after exposure to intervention night A

217. Self-reported sleep disturbance measured using on a 0-10 numerical scale, from "Not at all" to "Extremely" at morning after exposure to intervention night B

218. Self-reported sleep disturbance measured using on a 0-10 numerical scale, from "Not at all" to "Extremely" at morning after exposure to intervention night C

219. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to control

220. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to intervention night C

221. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to intervention night B

222. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to intervention night A

223. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to control

224. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to intervention night A

225. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to intervention night B

226. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at morning after exposure to intervention night C

227. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to control

228. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to intervention night C

229. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to intervention night B

230. Negative affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to intervention night A

231. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to control

232. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to intervention night A

233. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to intervention night B

234. Positive affect measured using using the Positive and Negative Affect Schedule (PANAS) at Evening after exposure to intervention night C

235. Glutamine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to control

236. Glutamine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night C

237. Glutamine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night B

238. Glutamine concentration (mmol/L) measured using NMR analysis of blood plasma at morning after exposure to intervention night A

239. Glyc/SPC, a ratio comparing the inflammatory glycoprotein signal (Glyc) to the phospholipidrelated signal (SPC), measured using NMR analysis of blood plasma at morning after exposure to control

240. Glyc/SPC, a ratio comparing the inflammatory glycoprotein signal (Glyc) to the phospholipidrelated signal (SPC), measured using NMR analysis of blood plasma at morning after exposure to intervention night A

241. Glyc/SPC, a ratio comparing the inflammatory glycoprotein signal (Glyc) to the phospholipidrelated signal (SPC), measured using NMR analysis of blood plasma at morning after exposure to intervention night B

242. Glyc/SPC, a ratio comparing the inflammatory glycoprotein signal (Glyc) to the phospholipidrelated signal (SPC), measured using NMR analysis of blood plasma at morning after exposure to intervention night C

243. Glyc measured using NMR analysis of blood plasma at morning after exposure to intervention night C

244. Glyc measured using NMR analysis of blood plasma at morning after exposure to control

245. Glyc measured using NMR analysis of blood plasma at morning after exposure to intervention night A

246. Glyc measured using NMR analysis of blood plasma at morning after exposure to intervention night B

247. Calcium disodium EDTA (CaEDTA) measured using NMR analysis of blood plasma at morning after exposure to control

248. CaEDTA measured using NMR analysis of blood plasma at morning after exposure to intervention night B

249. CaEDTA measured using NMR analysis of blood plasma at morning after exposure to intervention night C

250. CaEDTA measured using NMR analysis of blood plasma at morning after exposure to intervention night A

251. Insulin concentration measured using a Chemiluminescent Microparticle Immunoassay (CMIA) analysis of blood samples at morning after morning after exposure to control

252. Insulin concentration measured using a Chemiluminescent Microparticle Immunoassay (CMIA) analysis of blood samples at morning after exposure to intervention night A

253. Insulin concentration measured using a Chemiluminescent Microparticle Immunoassay (CMIA) analysis of blood samples at morning after exposure to intervention night B

254. Insulin concentration measured using a Chemiluminescent Microparticle Immunoassay (CMIA) analysis of blood samples at morning after exposure to intervention night C

Key secondary outcome(s)

1. Subjective sleepiness measured using the Karolinska Sleepiness Scale at evening after exposure to control

2. Subjective sleepiness measured using the Karolinska Sleepiness Scale at evening after after exposure to intervention night C

3. Subjective sleepiness measured using Karolinska Sleepiness Scale at evening after after exposure to intervention night B

4. Subjective sleepiness measured using Karolinska Sleepiness Scale at evening after after exposure to intervention night A

5. Cardiovascular activation in response to noise and vibration measured using change in heart rate (ECG) at occurring within the time window of each discrete railway event, during the control and each of the three intervention nights (23:00 to 07:00)

6. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to control

7. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to intervention night C

8. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to intervention night B

9. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to intervention night A

10. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to control

11. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to intervention night A

12. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to intervention night B

13. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at evening after exposure to intervention night C

14. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to intervention night C

15. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to intervention night B

16. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to intervention night A

17. Neurobehavioural speed measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix

reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to control

18. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to control

19. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to intervention night A

20. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to intervention night B

21. Neurobehavioural accuracy measured using 10 cognitive tests (motor praxis, visual object learning, fractal 2-back, abstract matching, line orientation, emotion recognition, matrix reasoning, digit symbol substitution, balloon analog risk, psychomotor vigilance) at morning after exposure to intervention night C

Completion date
12/06/2026

Eligibility

Key inclusion criteria
1. Live in or around the city of Gothenburg area (Sweden)

Healthy volunteers allowed
Yes

Age group
Adult

Lower age limit
18 Years

Upper age limit
30 Years

Sex
All

Total final enrolment
0

Key exclusion criteria

1. Age below 18 or above 30 years.
2. Usual weekday sleep and wake times that differ by more than ±1 hour from the study schedule (i.e., usual bedtime outside
22:00–00:00 or usual wake time outside 06:00–08:00), as confirmed by one week of actigraphy.
3. Body mass index (BMI) greater than 25 kg/m².
4. Regular use of sleep medication (prescribed or over-the-counter).
5. Hearing loss as measured during screening via pure tone audiometry.
6. Diagnosed sleep disorders.
7. High risk for sleep apnea based on the STOP-BANG questionnaire.
8. Engagement in shift work.
9. Use of tobacco, vaping, snus, or other nicotine products.
10. Pregnancy or breastfeeding.

Date of first enrolment
22/02/2026

Date of final enrolment
25/05/2026

Locations

Countries of recruitment
Sweden

Study participating centre
University of Gothenburg
Guldhedsgatan 5A
Gothenburg
Sweden
41320

Sponsor information

Organisation
University of Gothenburg

ROR
https://ror.org/01tm6cn81

Funder(s)

Funder type

Funder Name
Trafikverket

Alternative Name(s)
Swedish Transport Administration

Funding Body Type
Government organisation

Funding Body Subtype
National government

Location
Sweden

Results and Publications

Individual participant data (IPD) sharing plan

IPD sharing plan summary
Not expected to be made available

Study outputs

Output type	Details	Date created	Date added	Peer reviewed?	Patient-facing?
Protocol file			28/01/2026	No	No
Statistical Analysis Plan			28/01/2026	No	No